Features

- Inherently Matched LED Current
- Drives Up to **Four** LEDs from a **3.2V** Supply
- Drives Up to **Six** LEDs from a **5V** Supply
- High Efficiency: **84%** Typical
- Fast **1MHz** Switching Frequency
- 36V Rugged Bipolar Switch
- Low Profile SOT23-5 **Pb-Free** Packaging

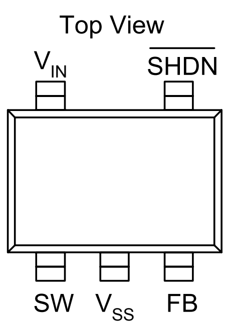
Applications

- **Cellular Phones**
- **PDAs, Hand-held Computers**
- **Digital Cameras**
- **MP3 Players**
- **GPS Receivers**

General Description

The AP1521 is a step-up DC/DC converter specifically designed to drive white LEDs with a constant current. The device can drive two, three or four LEDs in series from a Li-Ion cell. Series connection of the LEDs provides identical LED currents resulting in uniform brightness and eliminates the need for ballast resistors. The AP1521 switches at 1MHz that allows the use of tiny external components. A low 300mV feedback voltage minimizes power loss in the current setting resistor for better efficiency.

Pin Assignments



SOT23-5L

Pin Descriptions

Name	Description
SW	Switch Pin. Connect inductor/diode here. Minimize trace area at this pin to reduce EMI.
V_{SS}	GND pin
FB	Feedback Pin. Reference voltage is 310mV. Connect cathode of lowest LED and resistor here. Calculate resistor value according to the formula： R_{FB} = 310mV / I_{LED}
$\overline{SHDN}$	Shutdown Pin. Tie to 1.5V or higher to enable the device；0.4V or less to disable the device.
V_{IN}	Input Supply Pin. Must be locally bypassed.

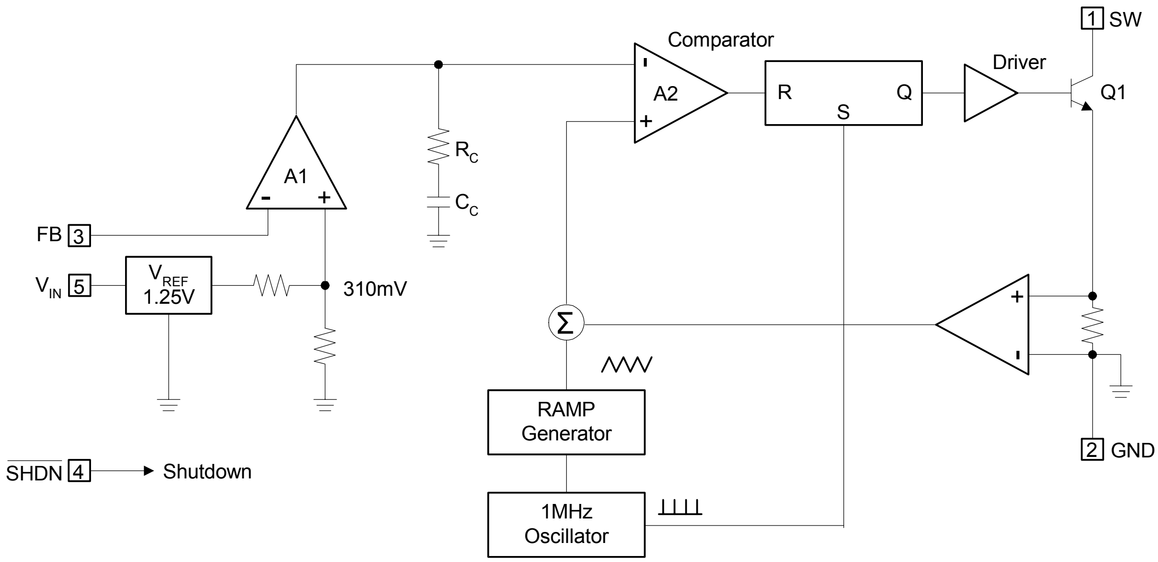
Ordering Information

AP1521 X X

Package — W: SOT23-5L

Packing — Blank : Tube; A : Taping

Block Diagram



Absolute Maximum Ratings

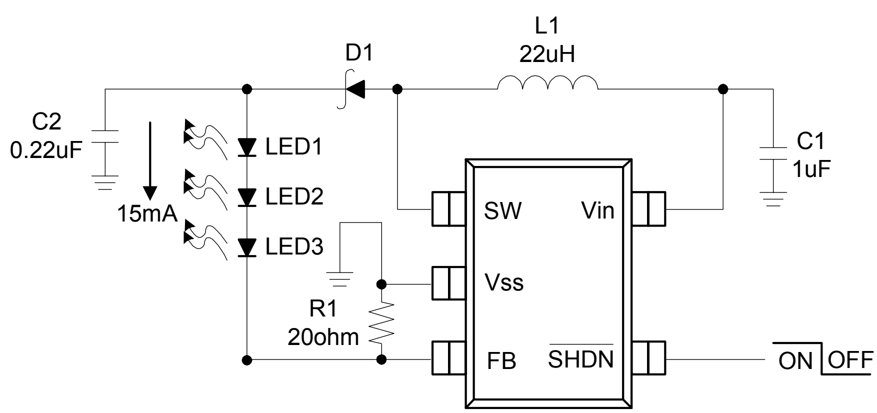
Symbol	Parameter	Rating	Unit
V_{IN}	VIN Pin Voltage	10	V
V_{SW}	SW Voltage	36	V
V_{FB}	Feedback Pin Voltage	10	V
V_{SHDN}	SHDN Pin Voltage	10	V
T_J	Maximum Junction Temperature	125	^oC
T_{LEAD}	Lead Temperature	300	^oC
T_{OPR}	Operating Temperature Range	-40 to +85	^oC
T_{STG}	Storage Temperature Range	-40 to +125	^oC

Caution The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any condition.

Electrical Characteristics (T_a=25°C, V_{IN} = 3V, V_{SHDN} = 3V, unless otherwise noted.)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Minimum Operation Voltage	-	2.5	--	--	V
V_{IN}	Maximum Operation Voltage	-	--	--	10	V
V_{FB}	Feedback Pin Voltage	-	280	310	340	mV
I_{FB}	Feedback Pin Bias Current	-	10	45	100	nA
	Supply Current		--	1.9	2.5	mA
		V_{SHDN} = 0V	--	0.1	1.0	μA
F_{SW}	Switching frequency		0.75	1.0	1.25	MHz
Duty	PWM Maximum Duty Cycle		85	90	--	%
I_{SW}	Switch Current Limit		--	320	--	mA
V_{SAT}	Switch V_{SAT}	I_{SW} = 250mA	--	350	--	mV
	Switch Leakage Current	V_{SW} = 5V	--	0.01	5	μA
V_{SHDN}	SHDN Pin Voltage High	Enable	1.5	--	--	V
V_{SHDN}	SHDN Pin Voltage Low	Disable	--	--	0.4	V
I_{SHDN}	SHDN Pin Bias Current		--	65	--	μA

Typical Application Circuit



C1, C2: X5R or X7R Dielectric
D1: Central Semiconductor CMDSH-3
L1: MURATA LQH3C-220 or Equivalent

Figure 1.

Applications Information

Capacitor Selection

The small size of ceramic capacitors makes them ideal for AP1521 applications. X5R and X7R types are recommended because they retain their capacitance over wider voltage and temperature ranges than other types such as Y5V or Z5U. A 1μF input capacitor and a 0.22μF output capacitor are sufficient for most AP1521 applications.

Inductor Selection

A 22μH inductor is recommended for most AP1521 applications. Although small size and high efficiency are major concerns, the inductor should have low core losses at 1MHz and low DCR (copper wire resistance).

Diode Selection

Schottky diodes, with their low forward voltage drop and fast reverse recovery, are the ideal choices for AP1521 applications. The forward voltage drop of a Schottky diode represents the conduction losses in the diode, while the diode capacitance (C_T or C_D) represents the switching losses. For diode selection, both forward voltage drop and diode capacitance need to be considered. Schottky diodes with higher current ratings usually have lower forward voltage drop and larger diode capacitance, which can cause significant switching losses at the 1MHz switching frequency of the AP1521. A Schottky diode rated at 100mA to 200mA is sufficient for most AP1521 applications.

LED Current Control

The LED current is controlled by the feedback resistor (R1 in **Figure 1**). The feedback reference is 310mV. The LED current is 310mV/R1. In order to have accurate LED current, precision resistors are preferred (1% is recommended). The formula and table for R1 selection are shown below.

R1 = 310mV/I_{LED} (See **Table 1**)

Table 1. R1 Resistor Value Selection

I_{LED} (mA)	R1 (Ω)
5	62
10	31
12	25.8
15	20.7
20	15.5

Open-Circuit Protection

In the cases of output open circuit, when the LEDs are disconnected from the circuit or the LEDs fail, the feedback voltage will be zero. The AP1521 will then switch at a high duty cycle resulting in a high output voltage, which may cause the SW pin voltage to exceed its maximum 36V rating. A zener diode can be used at the output to limit the voltage on the SW pin (**Figure 2**). The zener voltage should be larger than the maximum forward voltage of the LED string. The current rating of the zener should be larger than 0.1mA.

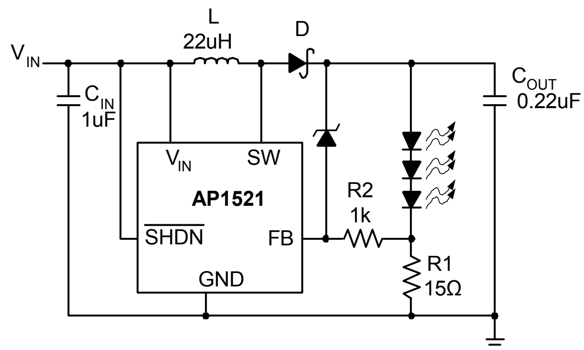


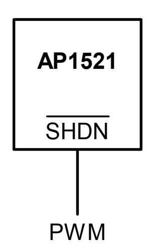
Figure 2. LED Driver with Open-Circuit Protection

Dimming Control

There are four different types of dimming control circuits:

1. Using a PWM Signal to $\overline{\text{SHDN}}$ Pin

With the PWM signal applied to the $\overline{\text{SHDN}}$ pin, the AP1521 is turned on or off by the PWM signal. The LEDs operate at either zero or full current. The average LED current increases proportionally with the duty cycle of the PWM signal. A 0% duty cycle will turn off the AP1521 and corresponds to zero LED current. A 100% duty cycle corresponds to full current. The typical frequency range of the PWM signal is 1kHz to 10kHz. The magnitude of the PWM signal should be higher than the minimum $\overline{\text{SHDN}}$ voltage.



■ Applications Information (Continued)

2. Using a DC Voltage
For some applications, the preferred method of brightness control is a variable DC voltage to adjust the LED current. The dimming control using a DC voltage is shown in **Figure 3**. As the DC voltage increases, the voltage drop on R2 increases and the voltage drop on R1 decreases. Thus, the LED current decreases. The selection of R2 and R3 will make the current from the variable DC source much smaller than the LED current and much larger than the FB pin bias current. For V_{DC} range from 0V to 2V, the selection of resistors in **Figure 3** gives dimming control of LED current from 0mA to 15mA.

3. Using a Filtered PWM Signal
The filtered PWM signal can be considered as an adjustable DC voltage. It can be used to replace the variable DC voltage source in dimming control. The circuit is shown in **Figure 4**.

4. Using a Logic Signal
For applications that need to adjust the LED current in discrete steps, a logic signal can be used as shown in **Figure 5**. R1 sets the minimum LED current (when the NMOS is off). R_{SET} sets how much the LED current increases when the NMOS is turned on.

Start-up and Inrush Current
To achieve minimum start-up delay, no internal soft-start circuit is included in AP1521. When first turned on without an external soft-start circuit, inrush current is about 200mA. If soft-start is desired, the recommended circuit and the waveforms are shown in **Figure 6**. If both soft-start and dimming are used, a 10kHz PWM signal on SHDN is not recommended. Use a lower frequency or implement dimming through the FB pin as shown in **Figures 3, 4 or 5**.

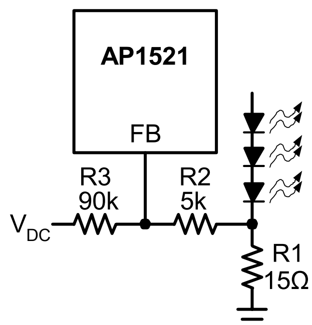


Figure 3. Dimming Control Using a DC Voltage

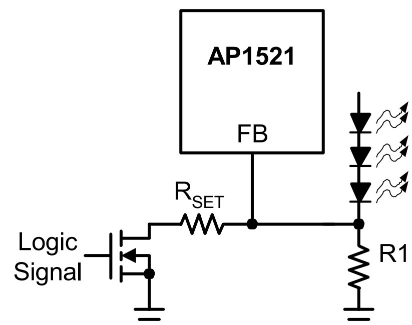


Figure 5. Dimming Control Using a Logic Signal

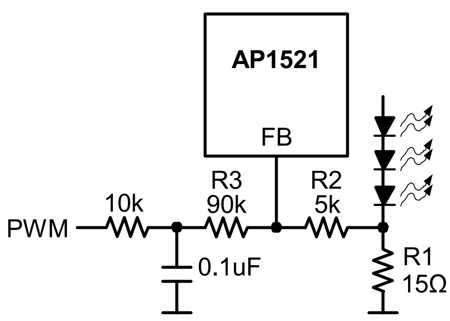


Figure 4. Dimming Control Using a Filtered PWM Signal

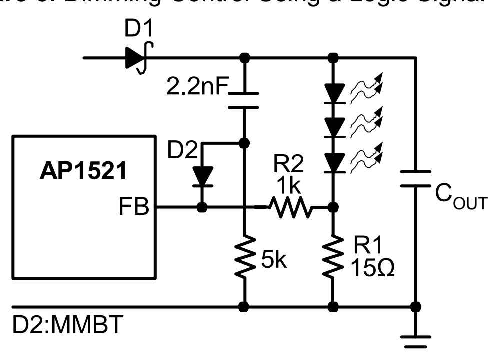
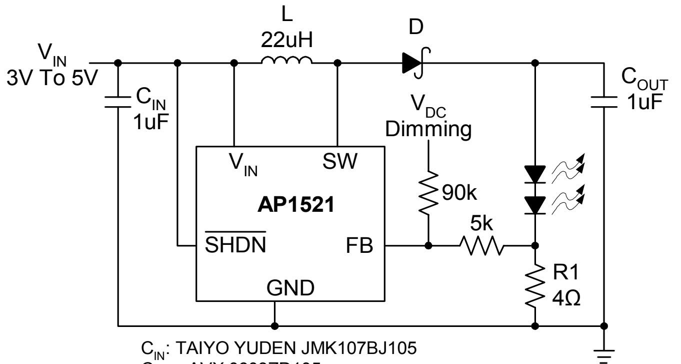


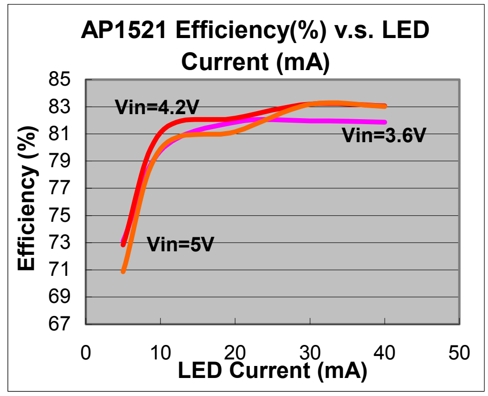
Figure 6. Recommended Soft-Startup Circuit

■ Typical Performance Characteristics

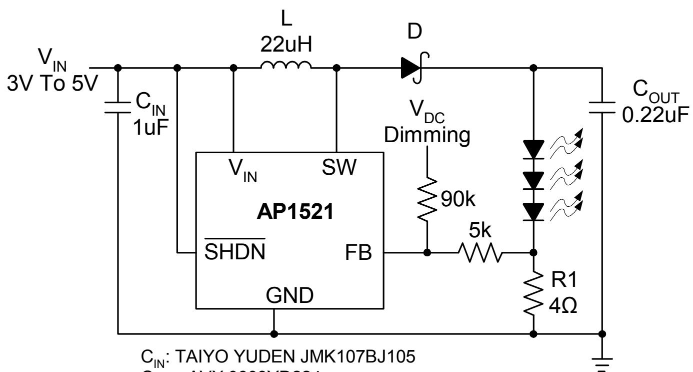
Li-Ion to Two White LEDs



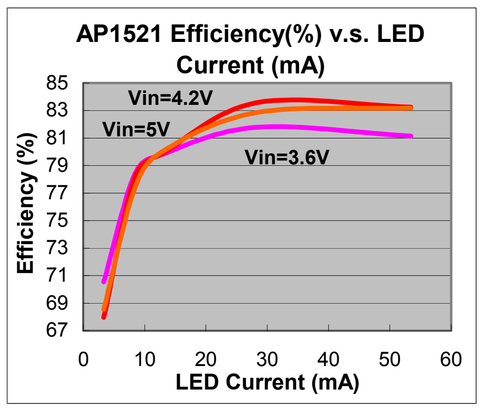
C_{IN}: TAIYO YUDEN JMK107BJ105
C_{OUT}: AVX 0603ZD105
D: CENTRAL CMDSH2-3
L: MURATA LQH3C220



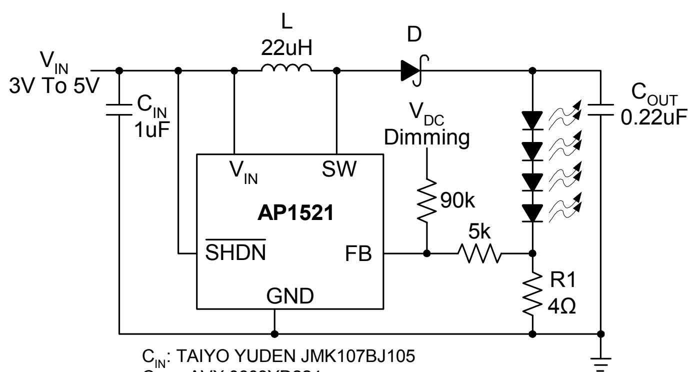
Li-Ion to Three White LEDs



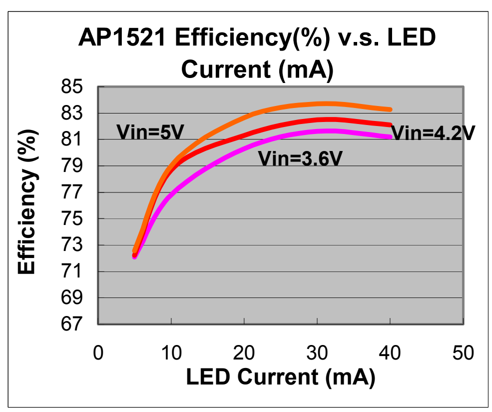
C_{IN}: TAIYO YUDEN JMK107BJ105
C_{OUT}: AVX 0603YD224
D: CENTRAL CMDSH-3
L: MURATA LQH3C220



Li-Ion to Four White LEDs

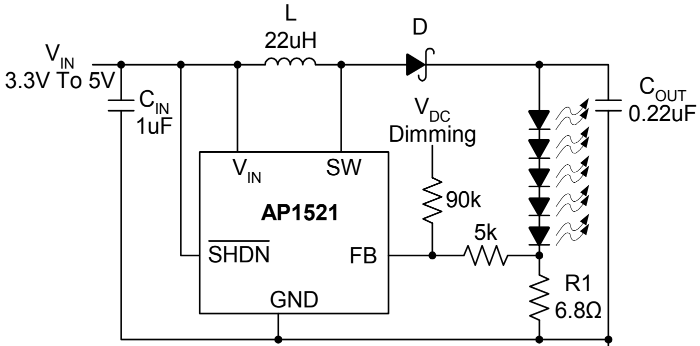


C_{IN}: TAIYO YUDEN JMK107BJ105
C_{OUT}: AVX 0603YD224
D: CENTRAL CMDSH-3
L: MURATA LQH3C220

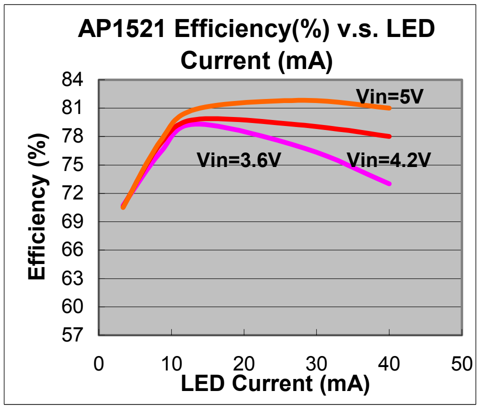


■ Typical Performance Characteristics (Continued)

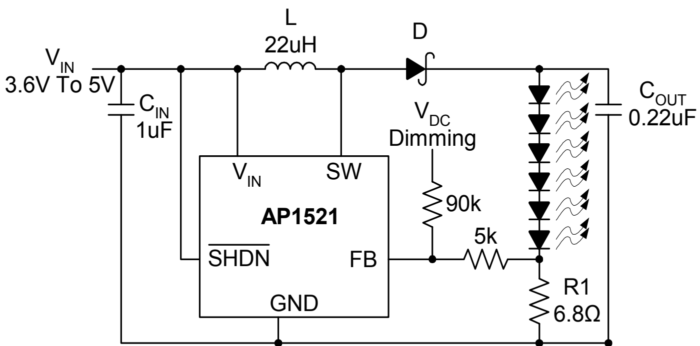
Li-Ion to Five White LEDs



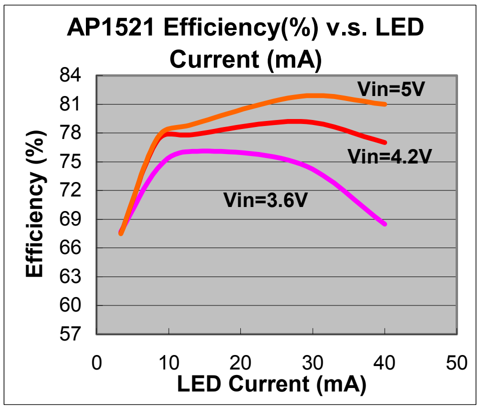
C_{IN}: TAIYO YUDEN JMK107BJ105
C_{OUT}: AVX 0603YD224
D: CENTRAL CMDSH-3
L: MURATA LQH3C220



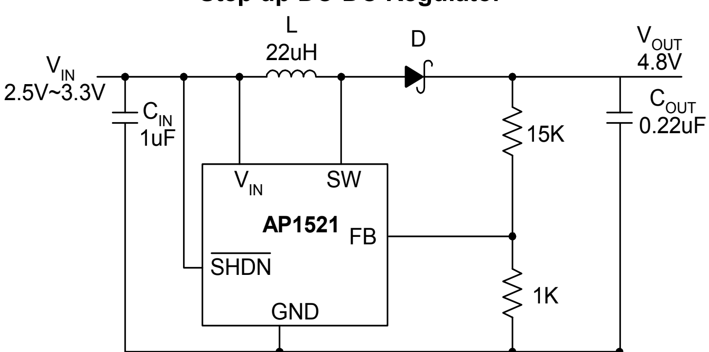
Li-Ion to Six White LEDs



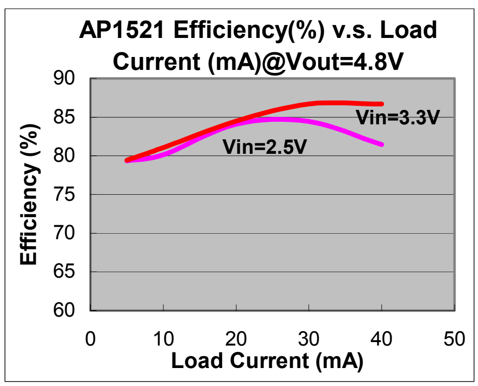
C_{IN}: TAIYO YUDEN JMK107BJ105
C_{OUT}: AVX 0603YD224
D: CENTRAL CMDSH-3
L: MURATA LQH3C220



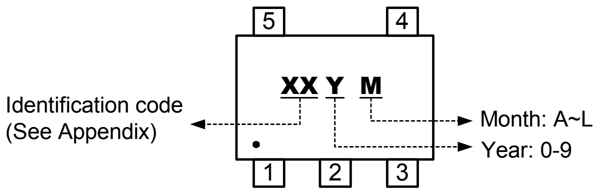
Step up DC-DC Regulator



C_{IN}: TAIYO YUDEN JMK107BJ105
C_{OUT}: AVX 0603YD224
D: CENTRAL CMDSH-3
L: MURATA LQH3C220



■ Marking Information

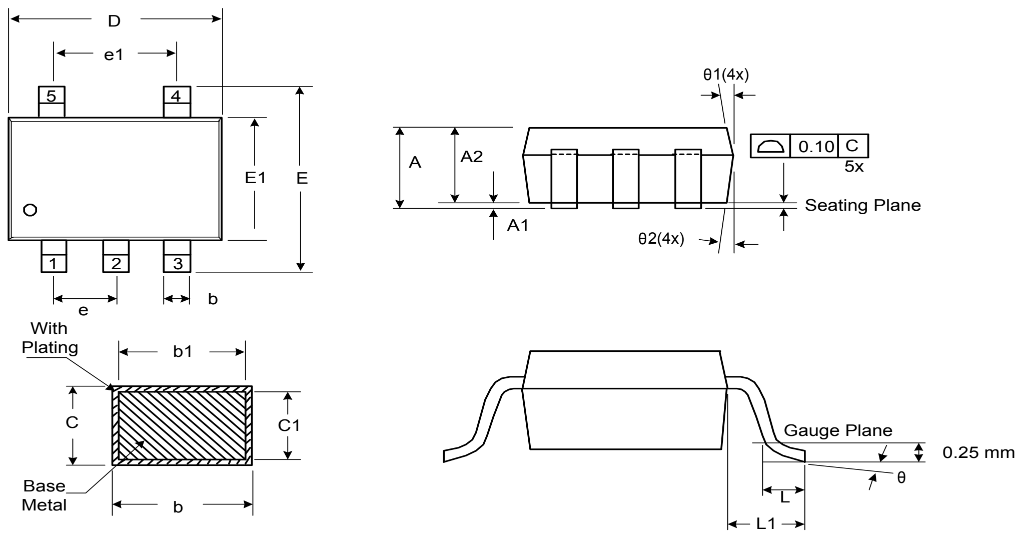


Appendix

Part Number	Package	Identification Code
AP1521	SOT23-5	FZ

■ Package Information

Package Type: SOT23-5L



Symbol	Dimensions In Millimeters			Dimensions In Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	1.05	1.20	1.35	0.041	0.047	0.053
A1	0.05	0.10	0.15	0.002	0.004	0.006
A2	1.00	1.10	1.20	0.039	0.043	0.047
b	0.25	-	0.55	0.010	-	0.022
b1	0.25	0.40	0.45	0.010	0.016	0.018
c	0.08	-	0.20	0.003	-	0.008
c1	0.08	0.11	0.15	0.003	0.004	0.006
D	2.70	2.85	3.00	0.106	0.112	0.118
E	2.60	2.80	3.00	0.102	0.110	0.118
E1	1.50	1.60	1.70	0.059	0.063	0.067
L	0.35	0.45	0.55	0.014	0.018	0.022
L1	0.60 Ref.			0.024 Ref.		
e	0.95 Bsc.			0.037 Bsc.		
e1	1.90 Bsc.			0.075 Bsc.		
θ	0^{o}	5^{o}	10^{o}	0^{o}	5^{o}	10^{o}
$\theta 1$	3^{o}	5^{o}	7^{o}	3^{o}	5^{o}	7^{o}
$\theta 2$	6^{o}	8^{o}	10^{o}	6^{o}	8^{o}	10^{o}